Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 The ratio of the power radiated per unit area by a surface to that of an ideal black surface at the same temperature.

2.2 Total scattered power ÷ total incident power; cloud formations and latitude.

2.3 The planet absorbs over its projected disc (πR^2) but the power spreads over the whole sphere ($4\pi R^2$), so the average over the surface is S/4.

2.4 Methane CH_4, water vapour H_2O, carbon dioxide CO_2, nitrous oxide N_2O.

2.5 The augmentation of the greenhouse effect due to human activities.

3.1 Absorbed: $0.60 \times 2200/4 = 330$ W/m^2; balance $\sigma T^4 = 330$; $T = (330/5.7 \times 10^{-8})^{1/4} = 276$ K.

3.2 Infrared photons match gaps between CO_2 molecular energy levels, so the molecules absorb them and gain energy; the excited molecules re-emit radiation in all directions, including back towards the surface; this returned energy adds to the surface energy budget, so the surface settles warmer than the no-atmosphere balance temperature.

3.3 Black body: $\sigma T^4 = 5.7 \times 10^{-8} \times 300^4 = 462$ W/m^2 (461.7); emissivity $= 300/462 = 0.65$. A black body of the same area radiates 462 W per unit area – 1.54× more.